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## **Measurement of Structural Changes to a Food Material during Dehydration**

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### **Abstract**

Rates of dehydration/rehydration are important quality parameters for dried products. Theoretically, if there are no adverse effects on the integrity of the tissue structure, it should absorb water to the same moisture content of the initial product before drying. The purpose of this work is to semi-automate the process of detection of cell structure boundaries as a food is dehydrated and rehydrated. This will enable food materials researchers to quantify changes to material's structure as these processes take place. Images of potato cells as they were dehydrated and rehydrated were taken using an electron microscope. Cell boundaries were detected using an image processing algorithm. Average cell area and perimeter at each stage of dehydration were calculated and plotted versus time. The results show that the algorithm can successfully identify cell boundaries. Further work will need to be done to improve detection of some missed boundaries and localisation of boundaries.

Keywords: food material, dehydration/rehydration, cell identification

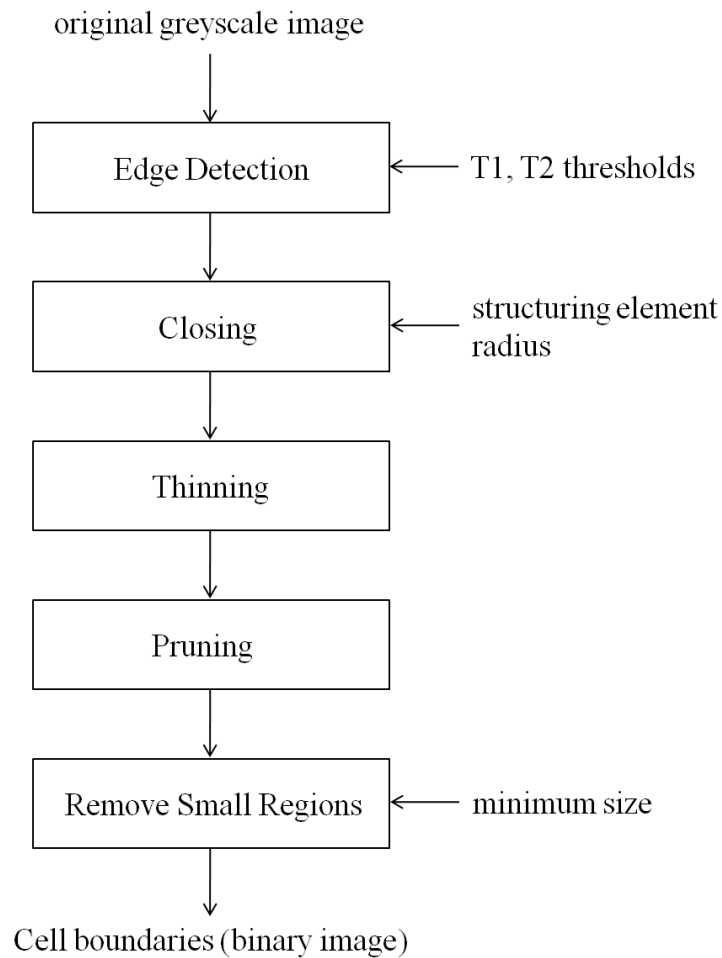
### **Introduction**

Rates of dehydration/rehydration are important quality parameters for dried products. Theoretically, if there are no adverse effects on the integrity of the tissue structure, it should absorb water to the same moisture content of the initial product before drying. However, the nature of the internal porous structure, and mechanical and elastic properties of the dried material, will influence the moisture uptake during rehydration. During these processes, different microstructures can be observed showing changes to the overall cell structure (Senadeera, 2000).

The purpose of this work is to semi-automate the process of detection of cell structure boundaries as a food is dehydrated and rehydrated. This will enable food materials researchers to quantify changes to material structure as these processes take place. For this work, images of potato cells as they were dehydrated and rehydrated were taken using an electron microscope. Cell boundaries were detected using an image processing algorithm. Cell area and perimeter at each stage of dehydration were calculated. Finally, average cell area and perimeter were plotted versus time.

### **Cell Boundary Detection**

The steps involved in the cell boundary detection algorithm are shown in Figure 1. These steps are described as follows.



**Figure 1. Cell boundary detection algorithm.**

### *Edge Detection*

Edge detection is used to identify cell boundaries. The Canny edge detector (Canny, 1986) was used. This algorithm was chosen since it uses a hysteresis method with two threshold values,  $T1$  and  $T2$ , where  $T1 > T2$ . An edge with a gradient  $>T1$  can be followed even if the gradient falls below  $T1$ , provided it stays above  $T2$ . Since cell boundaries appear to be variable in intensity, this method using a double threshold should be able to follow cell boundaries better than using a single threshold. This stage requires the two thresholds,  $T1$  and  $T2$ , to be passed in as parameters.

### *Morphological Closing*

Morphological closing, that is, dilation followed by erosion (Gonzalez, 2002), was then applied. The purpose of this stage is to join together edges that are not quite touching. A circular structuring element was used. This stage requires the radius of the structuring element to be passed in as a parameter.

### *Thinning*

The closing stage results in boundaries which are greater than one pixel wide. The thinning algorithm of (Zhou, 1995) was used to reduce boundaries to one pixel in width.

### *Pruning*

The results of the thinning algorithm might still contain some burrs, that is, small branches which do not completely separate two cells. These were removed as follows:

1. For every pixel equal to one in the boundary image, the hit-and-miss transform was performed using the two structuring elements of Figure 2, in each of their 90 degree rotations (Fisher, 2003).
2. If the hit-and-miss transform is true for one of the structuring elements of Figure 2 or its rotations, this means this is a pixel at the end of a burr. Set this pixel to zero.
3. Repeat until there is no further change to the boundary image.

0	0	0
0	1	0
		0

0	0	0
0	1	0
0		

**Figure 2. Structuring elements for the hit-and-miss transform.**

### *Removing Small Regions*

This step removed small connected regions from the boundary image, since it was considered that these regions represent structures that are totally enclosed within a cell. For every boundary pixel, the number of 8-connected neighbours were counted, followed by the neighbours of the neighbours, until all pixels that are part of a boundary were counted. If the count was less than a given minimum, then all pixels in the boundary were removed (i.e. set to zero). This stage requires that the minimum number of connected boundary pixels be passed in as a parameter.

### **Calculation of Cell Parameters**

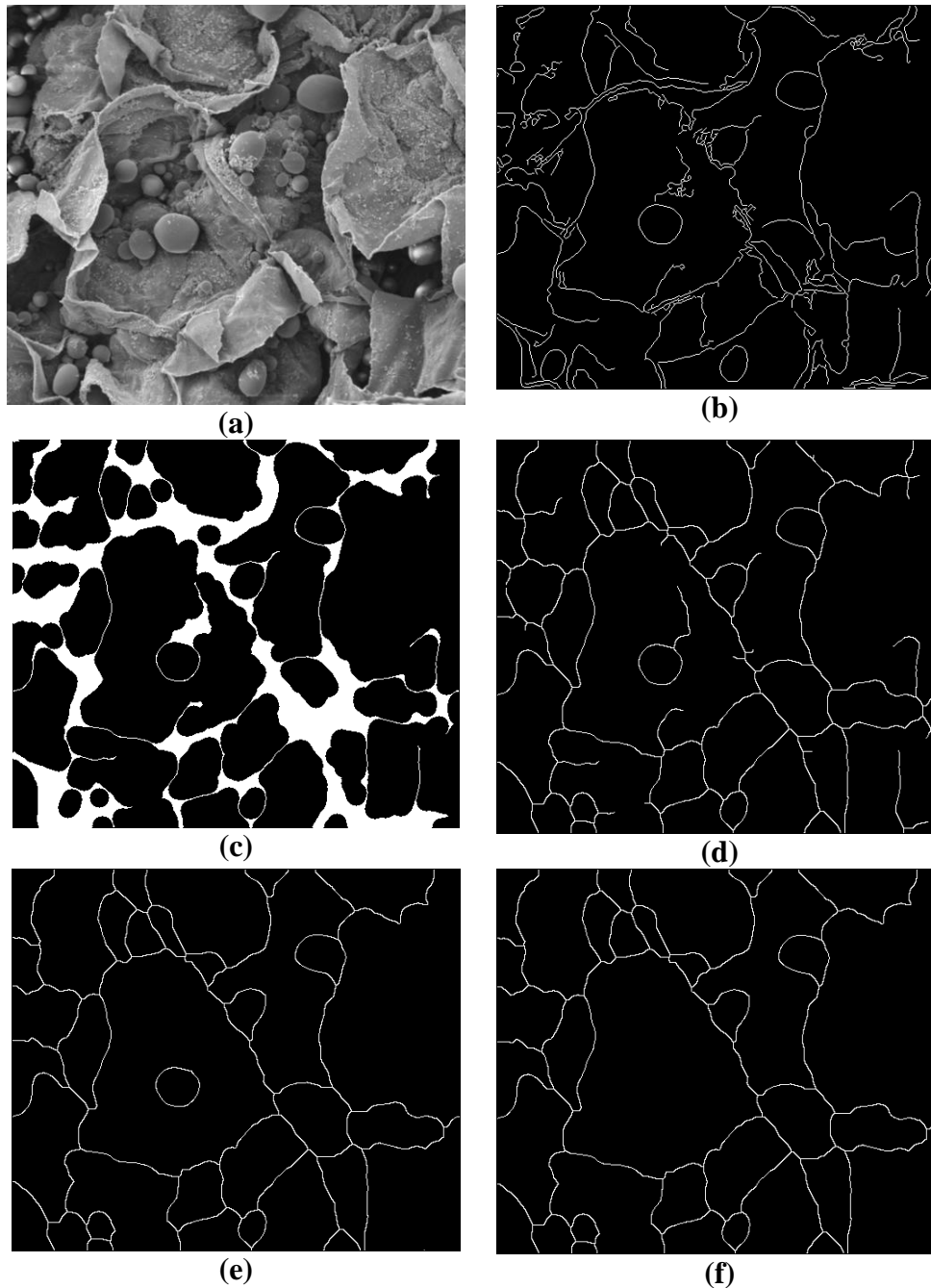
Once cell boundaries were detected, the next step was to use these to calculate cell parameters. It was decided to start with cell perimeter and area since these are fairly simple to compute. It was speculated that perimeter and area should decrease as the dehydration time increases.

Before the perimeter and area could be computed, it was necessary in some cases to merge adjacent regions into one cell. This is because, in some cases, the cell boundary detection algorithm would split a cell into several regions. Code was written to allow the user to interactively click on adjacent regions to identify them as being part of the same cell. Once the region or regions comprising a cell were identified, a region growing algorithm was used to find all connected pixels that are part of a cell. During the dehydration process, a total of eleven images were taken, at intervals of one hour. Each of these images was processed with the cell boundary detection algorithm. Where necessary, adjacent regions belonging to the same cell were identified. Once a number of cells in each image were selected, the average perimeter and area for the cells in the image were computed.

### **Results**

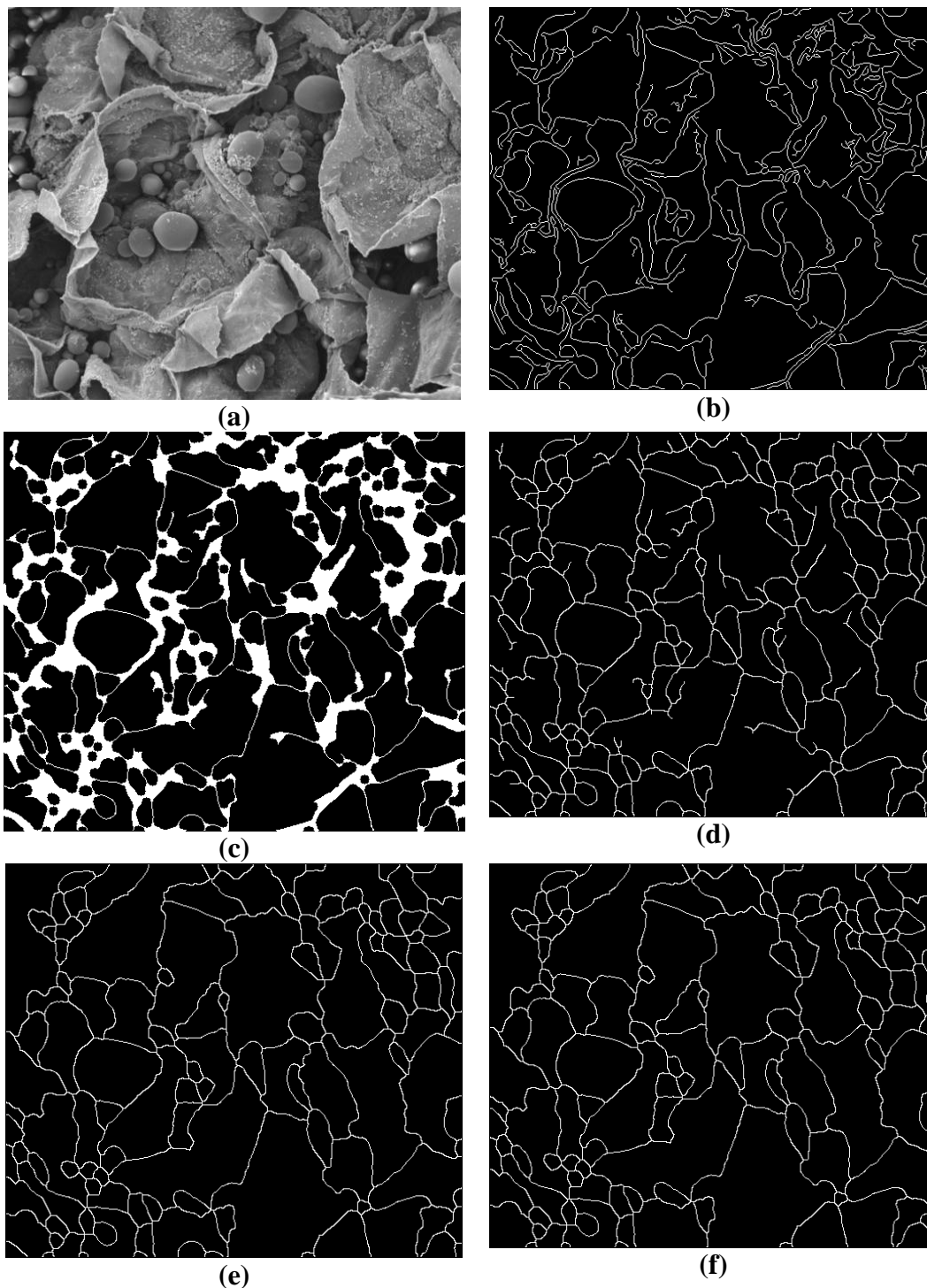
Figure 3 shows the results of applying the cell boundary detection algorithm to an image taken before dehydration. The original image is shown in Figure 3(a), while (b–f) show the results of

edge detection, closing, thinning, pruning and removing small regions respectively. In Figure 3(e), it can be seen that a number of small burrs have been removed, and in (f), the small roughly circular region in the mid-left of the image (corresponding to a starch grain) has been removed.



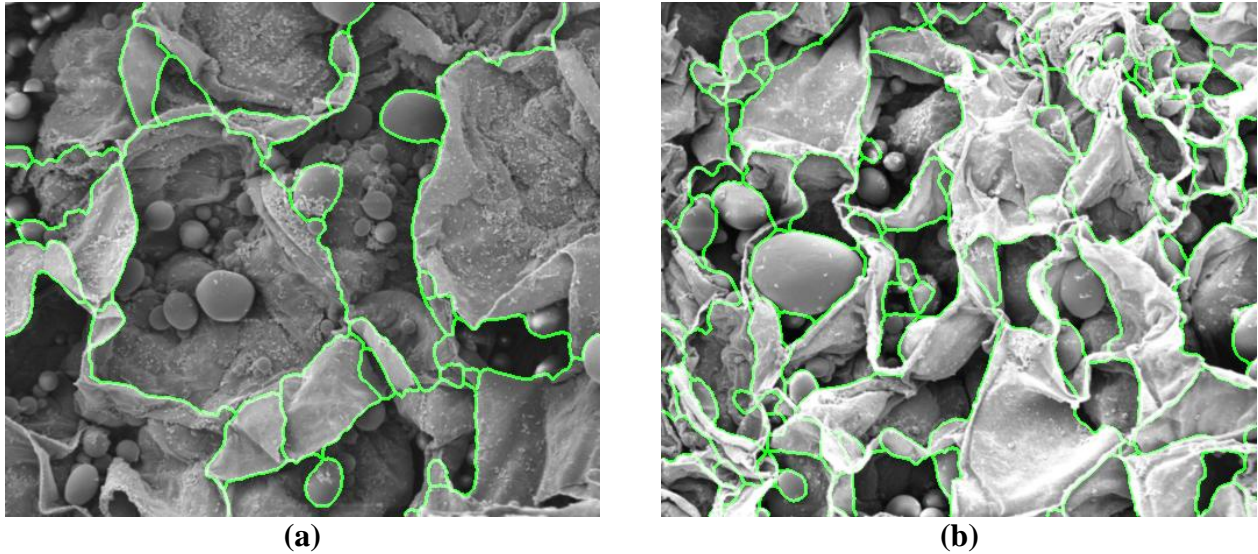
**Figure 3. Results of cell boundary detection algorithm on image before dehydration (a) greyscale image, and results of (b) edge detection, (c) closing, (d) thinning, (e) pruning, and (f) removal of small regions.**

Figure 4 shows the results of applying the cell boundary detection algorithm to an image taken after the material had been dehydrated for five hours. The original image is shown in Figure 4(a), while (b–f) show the results of edge detection, closing, thinning, pruning and removing small regions respectively.

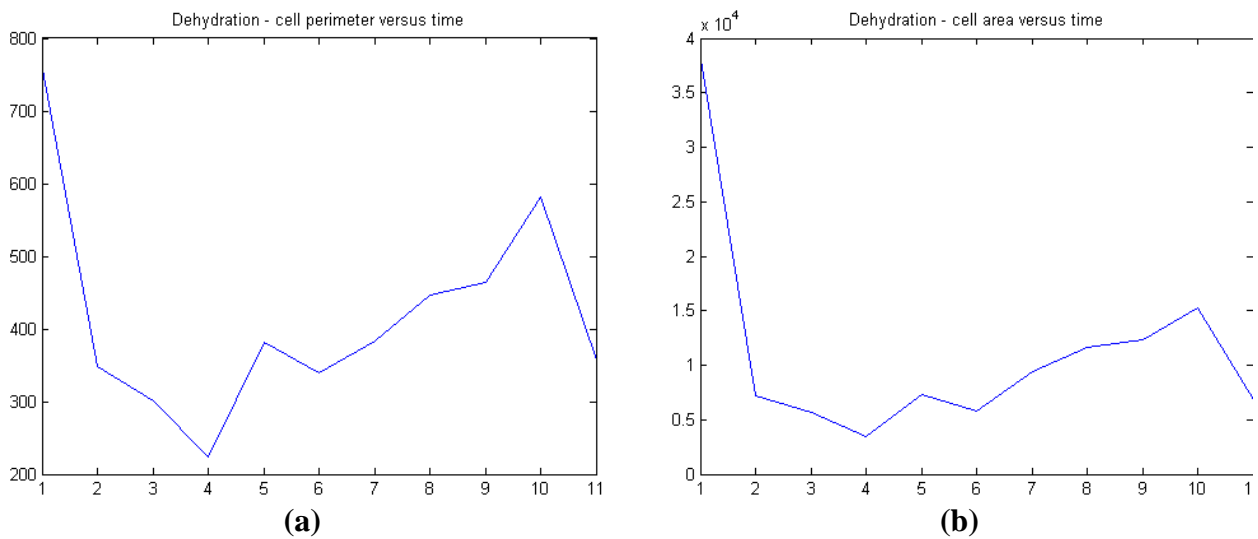


**Figure 4. Results of cell boundary detection algorithm on image after five hours of dehydration (a) greyscale image, and results of (b) edge detection, (c) closing, (d) thinning, (e) pruning, and (f) removal of small regions.**

In Figure 5, the detected cell boundaries for Figure 3 and Figure 4 have been superimposed on the original images. Figure 6 shows plots of the average perimeter and area versus time in hours.



**Figure 5. Cell boundaries superimposed on original images (a) image from Figure 3, (b) image from Figure 4.**



**Figure 6. Average cell parameters versus dehydration time in hours (a) perimeter (b) area.**

## Discussion

The results show that the algorithm can successfully identify cell boundaries. In some cases, however, changes in pixel intensity do not correspond to cell boundaries. This could occur where part of a cell wall becomes folded over, or could be due to other structures such as starch grains. From a visual comparison between the detected edges and the original images, it appears that the algorithm works best for the image before any dehydration has taken place. This could be because as dehydration proceeds the images tend to contain more complex structures and fine edges.

As shown in Figure 6, the average perimeter and area initially tend to decrease with time. However, there is a slight increase in both perimeter and area after about five hours. It is possible that cells may start to shrivel and their structures “open up” again after a certain dehydration time, before “closing” again.

Further work will include investigation into improving the cell boundary detection algorithm, such as detection of some missed boundaries and improved localisation. Other methods of detecting cell boundaries, such as the variance based method of (Bradhurst, 2008), could be investigated. The goal is to analyse rehydration images as well, and to determine the differences between the original and rehydrated materials and quality of rehydrated products.

## References

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